Using C- and L-band radar observations to retrieve soil rms height and moisture to improve SWE retrieval

Jiyue Zhu[1], Leung Tsang[1], Do-Hyuk "DK" Kang[2,3], and Edward Kim[2]

[1]Radiation Laboratory, Department of Electrical Engineering and Computer Science, The University of Michigan, Ann Arbor, 48109-2122 MI USA
[2]NASA Goddard Space Flight Center, Greenbelt, MD 20771, USA
[3]ESSIC, University of Maryland, College Park, MD, 20740, USA

Introduction

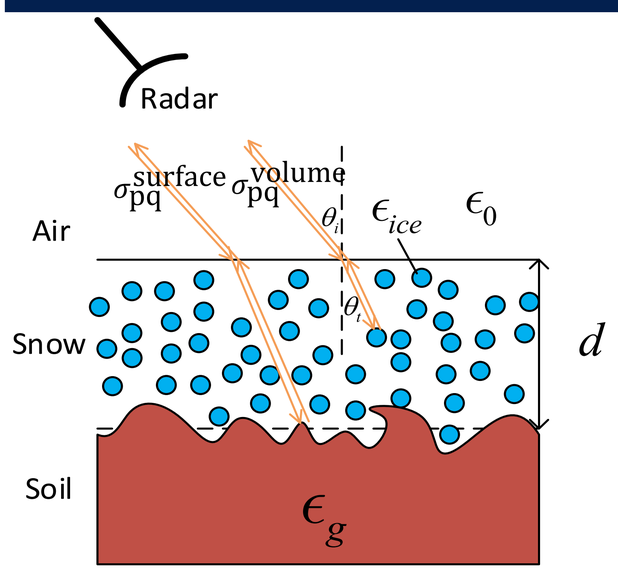
The NASA GSFC SWESARR, the Canadian terrestrial snow measurement mission (TSMM) and the prior NASA SCLP and ESA CoReH2O have similar SWE (snow water equivalent) retrieval concepts of using X- (10GHz) and Ku-(17GHz) band volume backscattering method:

- SWE retrieval shows a satisfactory performance by assuming a priori information of snow scattering albedo (equivalent to snow grain size) and soil surface scattering (Zhu et al., 2018).
- Recent campaigns for validation: SWESARR campaign in SnowEx 2019, Canadian TVC campaign in the winter of 2018.

However, X and Ku band radar observations have surface scattering of soil that depend on rms height and soil moisture (SM). In this paper, we propose to improve SWE retrieval by

- **Using C and L-band data to retrieve soil rms height and SM**
- **Using retrieved rms height and SM to get surface scattering at X and Ku band**

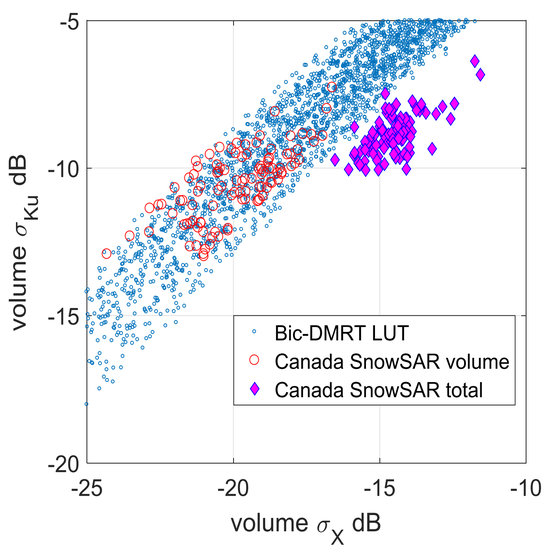
Motivation and Background



$$\sigma_{pq}^{total} = \sigma_{pq}^{volume} + \sigma_{pq}^{surface} \exp\left(-\frac{2\tau}{\cos\theta_t}\right)$$

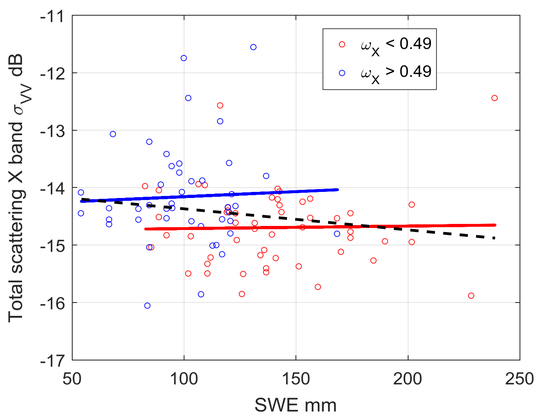
- Surface scattering from ground
- Volume scattering from snowpack **giving SWE**
- Radar data: volume scattering + surface scattering

Canada SnowSAR 2013 data

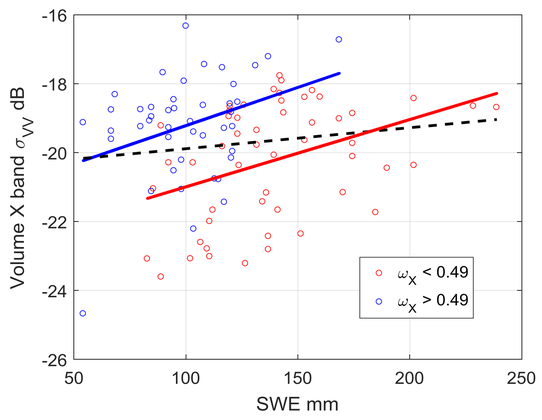


- Volume scattering of SnowSAR within model predictions
- Surface scattering affects more in X band than Ku band
- Larger dynamic range in volume scattering

Total backscatter vs. SWE

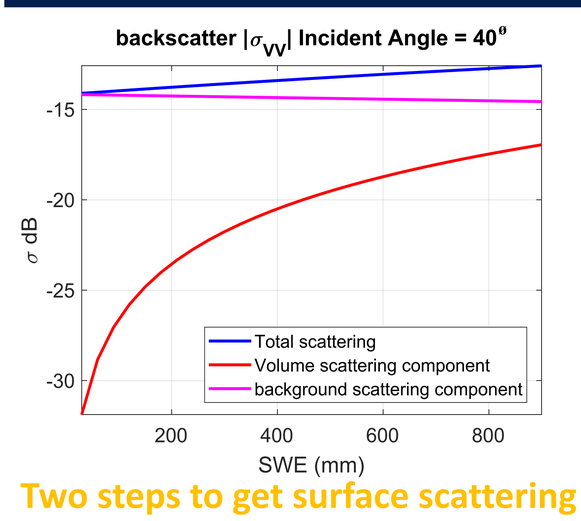


Volume backscatter vs. SWE



- Classification of backscatter through equivalent grain size (represented by albedo) improves its sensitivity to SWE
- Subtraction of surface scattering further restores the high sensitivity of backscatter to SWE

Procedure: surface scattering at X and Ku-band



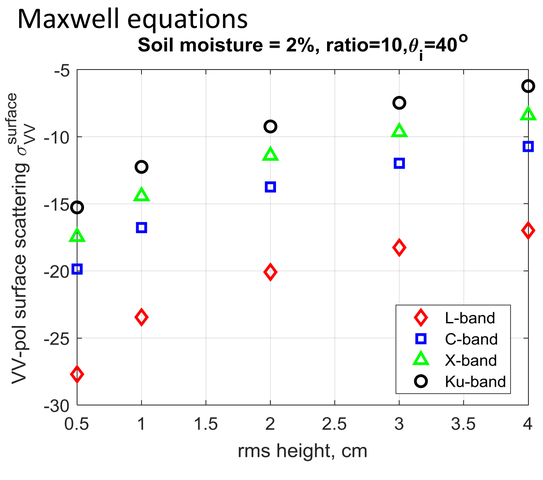
Snowpack: grain size 1mm and snow density $0.275\mathrm{g/cm^3}$
Soil : permittivity of $4 + 0.5\mathrm{i}$ and rms height 1cm.

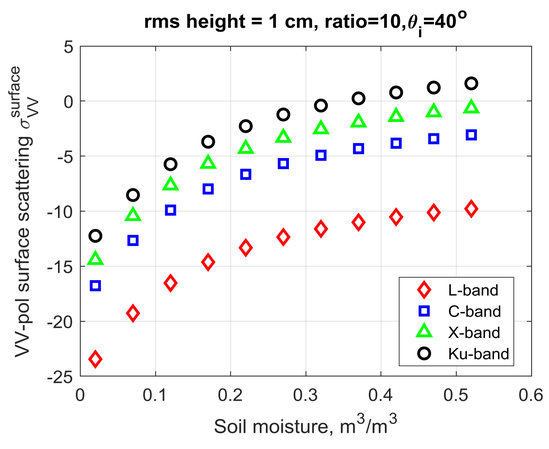
Volume scattering is computed by the DMRT-bicountinuous model (Tan et al, 2015
The surface scattering is calculated by Oh model (Oh et al, 1992).

- The total backscatter is dominated by surface scattering at C band, especially for SWE<200mm

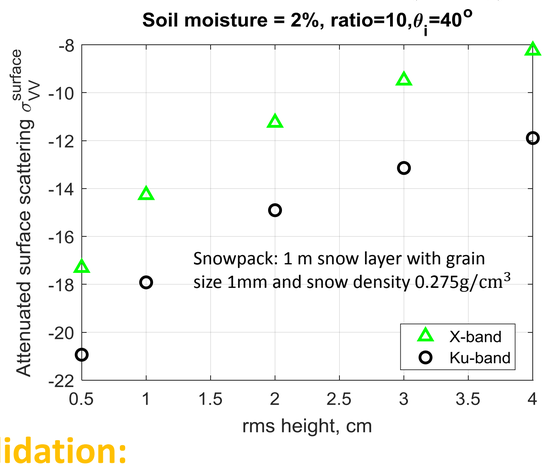
Two steps to get surface scattering of soil at X and Ku band

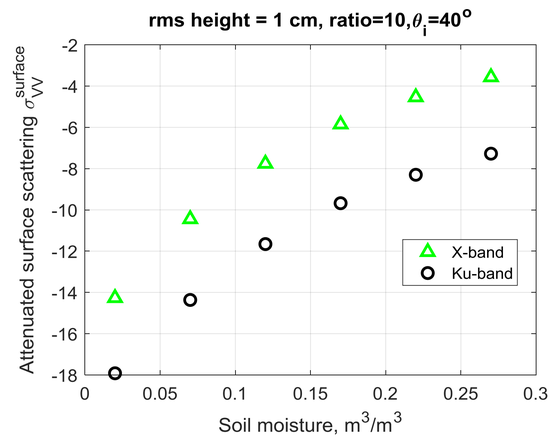
1. Use C (blue) and L (red) band data to retrieve rms height and SM
2. Use values of rms height and SM to get surface scattering at X (green) and Ku (black) band from Maxwell equations





Surface scattering component=$\sigma_{pq}^{surface} \exp\left(-\frac{2\tau}{\cos\theta_t}\right)$ at X (green) and Ku (black) attenuated by snowpack



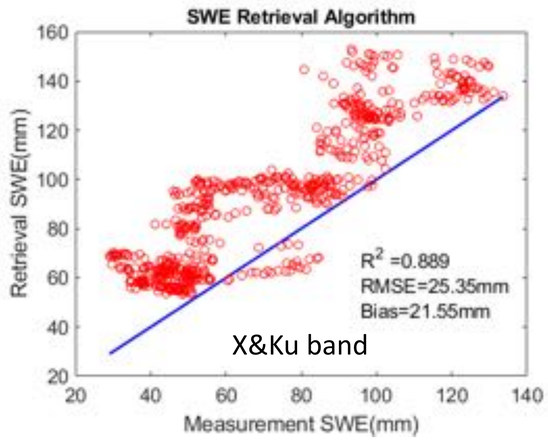


Validation:

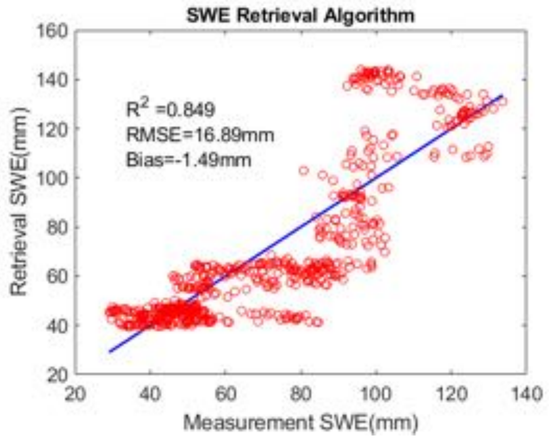
- Scatterometer data is from the Finnish NoSREx which was conducted near the town of Sodankylä in northern Finland in the winter of 2010-2011 . The Scatterometer is operating from X- to Ku-band (10.2, 13.3, and 16.7 GHz) and was installed on tower platforms located in a forest clearing area.

$\epsilon_g = 4 + 1i$, rms = 1cm [5]	VV	VH
Sentinel 1 data (C-band)	**-11.01dB**	**-19.15dB**
NMM3D LUT	**-11.09dB**	**-19.76dB**

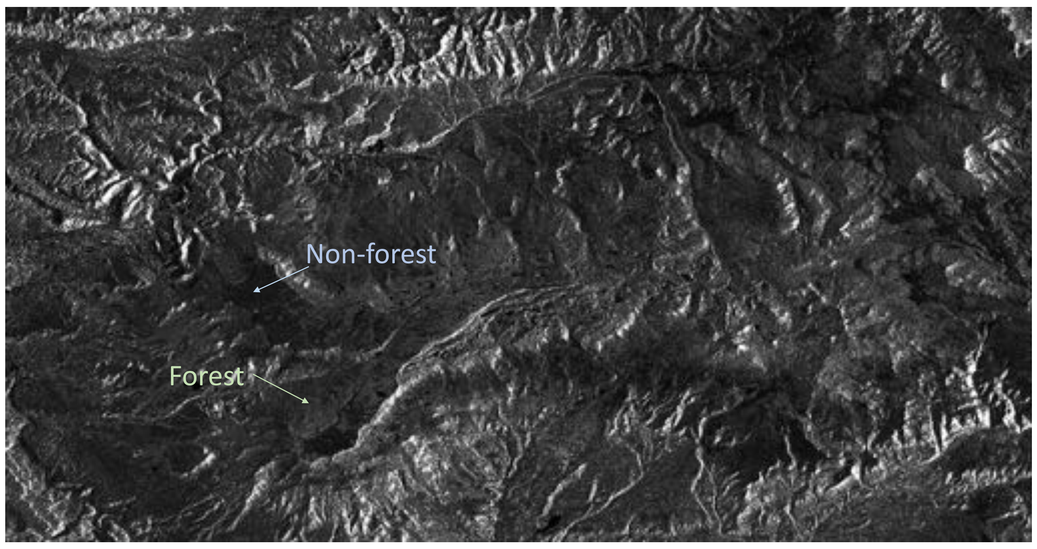
Retrieval without surface scatteing



Retrieval with surface scatteing



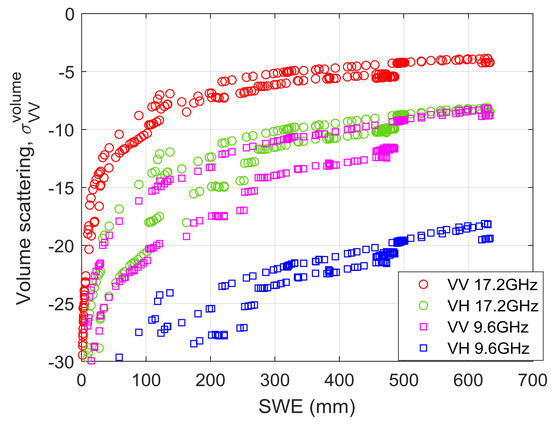
- Without surface scattering, retrieved SWE are larger than measured SWE
- With surface scattering, retrieval improved significantly

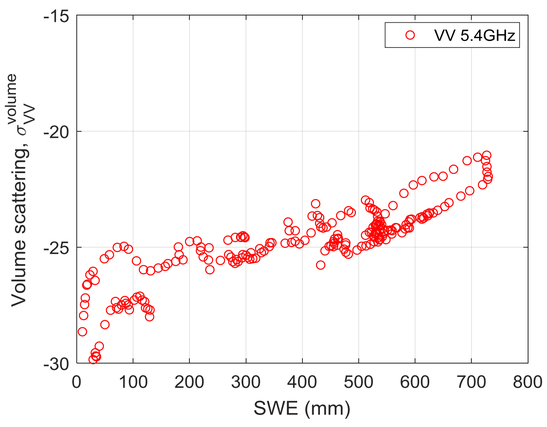


Sentinel 1 data (C-band radar observations) at Feb 12th , 2017 within the SnowEx 2017 campaign period

SWE retrieval for thick snow with C band

The snowpack is generated by snow physical model





- Backscatter at X and Ku band saturate for SWE >400mm: 1dB range
- C band backscatter hold sensitivity for SWE > 400mm: 4dB range

References

[1] Zhu, J., Tan, S., King, J., Derksen, C., Lemmetyinen, J., & Tsang, L. (2018), Forward and Inverse Radar Modeling of Terrestrial Snow Using SnowSAR Data, IEEE Trans. Geosci. Remote. Sens., 56(12), 7122-7132, doi:10.1109/TGRS.2018.2848642..

[2] Tan, Shurun, et al. "Modeling both active and passive microwave remote sensing of snow using dense media radiative transfer (DMRT) theory with multiple scattering and backscattering enhancement." IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol.8, No.9, pp. 4418-4430, September 2015.

[3] Oh, Y., Sarabandi, K., & Ulaby, F. T. (1992), An empirical model and an inversion technique for radar scattering from bare soil surfaces, IEEE Trans. Geosci. Remote Sens., 30(2), 370-381. doi: 10.1109/36.134086.

[4] Liao, T.-H., Tsang, L., Huang, S., Kim, S.-B., Tanelli, S., Niamsuwan, N., & Jaruwatanadilok, S. (2016b), "Co-polarized and Cross polarized Backscattering from Random Rough Soil Surfaces from L-band to Ku-band Using Numerical Solutions of Maxwell's Equations with Near Field Precondition," IEEE Trans. Geosci. Rem. Sens., vol. 54, no. 2, pp. 651-662

[5] Lemmetyinen, J., Derksen, C., Rott, H., Macelloni, G., King, J., Schneebeli, M., ... & Pulliainen, J. (2018). Retrieval of effective correlation length and snow water equivalent from radar and passive microwave measurements. Remote Sensing, 10(2), 170.